MTP Medical Technology Program

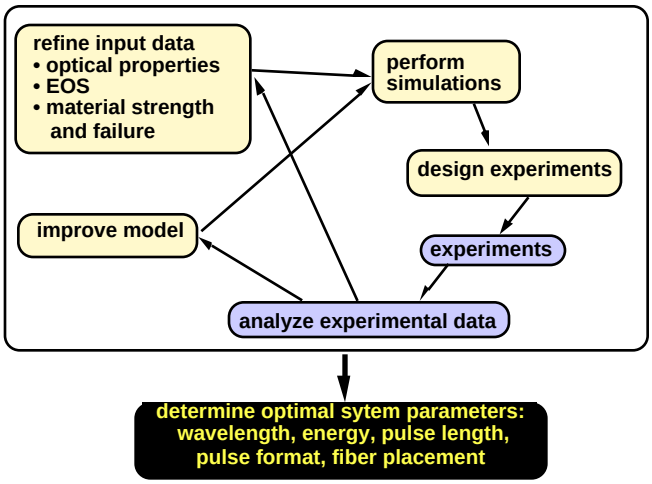
U.S. Department of Energy

UCRL-MI-129407

Laser Tissue Interaction Modeling

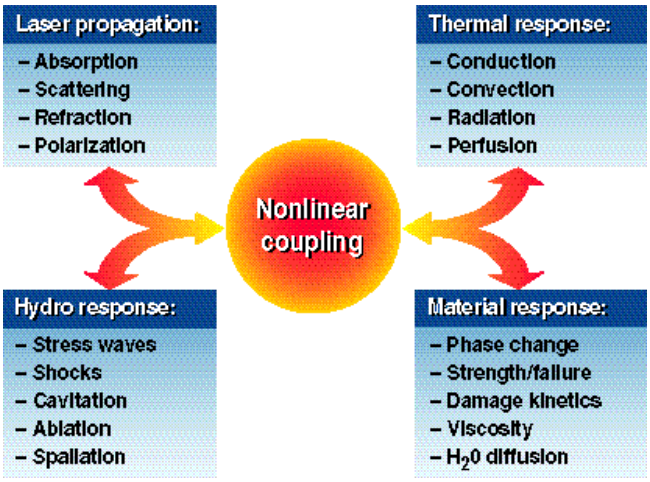
Computer Modeling

Scientists at the Lawrence Livermore National Laboratory are using computers to model the interaction of laser light with biological tissues. Modeling is used to design experiments and to gain a deeper understanding of specific laser-medical processes. It enables more rapid development of instruments and the genesis of new ideas.



The modeling process.

A project to develop a specific instrument or procedure will generally involve iteration between modeling and experiment, converging on a set of optimized design parameters.



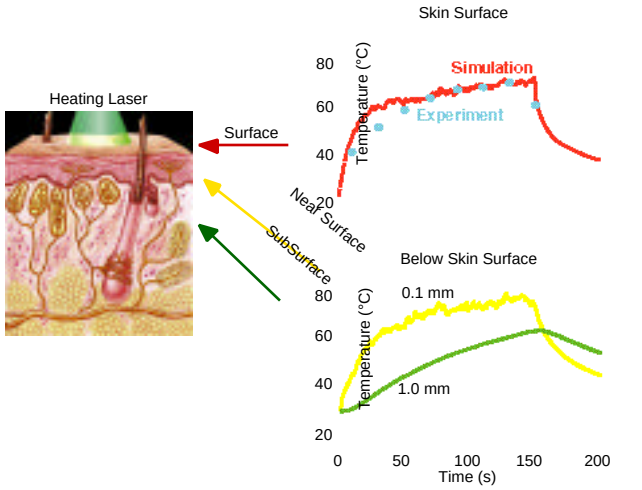
LLNL has unique capabilities for multi-process modeling.

The modeling group at Livermore uses the LATIS computer program. LATIS is based on LASNEX which incorporates over 25 years of experience in computer modeling of laser-matter interaction applied to Laser Fusion. LATIS is a time-dependent two-dimensional program. It considers four categories of physical processes and their non-linear couplings: laser propagation, thermal response, material response, and hydrodynamical response.

The uses of LATIS have been in two classes: photothermal and photomechanical, according to whether the desired effects are thermal or mechanical. In the photothermal class, LATIS has been used to study the effects of dynamic optical properties on laser dosimetry, to design welding of intravascular patches, to study the thermal environment for general tissue welding, and to analyze clinical data for a commercial laser system which treats benign prostate hyperplasia. In the photomechanical area, we have applied LATIS to study high-precision tissue ablation with ultra-short pulses, to study the use of cavitation and vapor bubbles to break up intravascular blood clots, to model the generation of mechanical stress waves in tissues, and to quantify the removal of tissue via laser induced spallation.

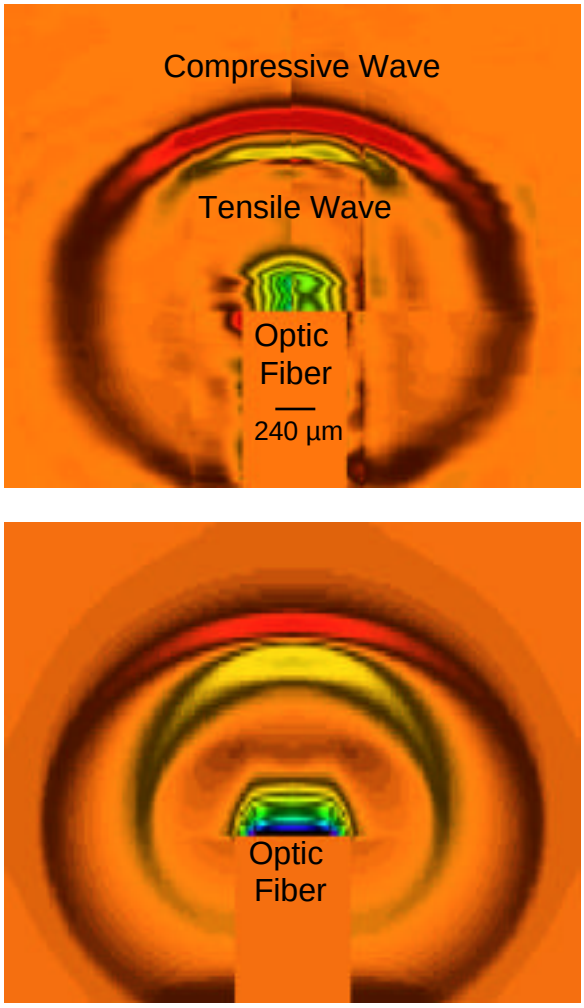
Applications

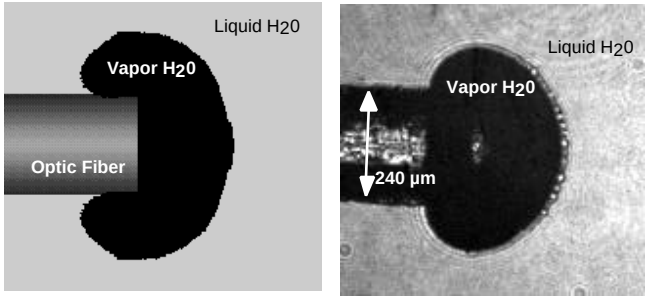
Laser Tissue Welding: We can accurately model the temperature rise from the application of thermal energy to tissue. Experiments validate the simulated skin surface temperatures. These validated simulations provide subsurface temperature predictions that cannot be experimentally measured.



Skin surface temperatures are accurately predicated through the use of modeling.

Laser-initiated Stress Waves: Stress waves can be used to locally modify or disrupt tissue. Therapeutic applications include emulsification of kidney stones, blood clots, and/or atherosclerotic plaque, removal of tissue via spallation, and local delivery of large drug molecules into cells.





Model calculations of the dynamics of laser-initiated vapor bubbles (left) have been verified by comparison to experimental photographs (right). The models have been used to design a system for treatment of stroke by removal of intravascular blood clots.

Continued Research

A modern three-dimensional program, called LATIS3D is currently under development.
In addition to the extra dimension, which will allow more realistic treatments of clinical procedures, LATIS3D incorporates a modern object-oriented design and a richer set of physical processes. LATIS3D will be made available to external users. In the future modeling will be used for patient-specific treatment planning and for physician training.

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